Uncertainties in Solar Opacities

Carlos A. Iglesias
Lawrence Livermore National Laboratory

The predicted solar neutrino production is sensitive to the temperature at the Sun's center which in turn depends on the input physics to the solar models. Furthermore, observational Helioseismology continues to improve and promises to constrain solar structure calculations.[1] An important input to the models is the radiative opacity which has also received attention.[2-7] Unfortunately, the matter conditions in the solar interior are sufficiently hot and dense to make impossible direct experimental determination of the opacities. Consequently, uncertainties in the opacity must be determined by either indirect tests (e.g., comparisons of observations and solar models [8]) or theoretical estimates. The former approach has proven useful for constraining opacities not only in the solar problem,[8] but also in other aspects of stellar evolution.[9] The present discussion will concentrate on the latter approach. Although, there are a variety of possible sources to solar opacity uncertainties, the emphasis here will be on the ionization equilibrium, which affects the opacity near the bottom of the convection zone, and plasma effects, which have the most impact near the solar center.

Discrepancies among the various ionization equilibrium models suggest that the opacities near the bottom of the solar convection zone are uncertain by 10-20%. On the other hand, in the solar center the main correction to the Kramers electron-ion bremsstrahlung classical cross-section is the introduction of a Gaunt factor. Other plasma effects cause less than 1% corrections to the Rosseland mean opacity. In Thomson scattering relativistic corrections are small while Coulomb and degeneracy correlations are significant. Furthermore, dispersion effects enhance the photon scattering by about 2 percent. Note that the photoabsorption from bound electrons in heavier elements slightly reduces these error estimates. Finally, recent solar opacity calculations include the dominant plasma corrections to these absorption processes. On the basis of the present results, the omissions only introduce small errors to the total opacity of the solar center.

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